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Prevalence of prenatal alcohol use among Aboriginal and non-Aboriginal women in the Northern Territory, Australia: estimate from perinatal, emergency, and admission datasets

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Abstract

Background Prenatal Alcohol Use (PAU) has detrimental effects on mothers and their children. Robust estimates of the prevalence of PAU and associated risk factors are critical for informing interventions to reduce adverse health impacts. This study aimed to estimate the prevalence and risk factors of PAU among Aboriginal and non-Aboriginal mothers in the Northern Territory of Australia.

Methods We used linked individual-level records from the NT perinatal register, hospital admissions, and emergency department presentations to estimate the prevalence of PAU for all 19,588 births to NT-resident women from 2013 to 2017. Permutation analysis was used to create four PAU categories: no PAU, early PAU (alcohol use in early pregnancy only), continued PAU (alcohol use in early and late pregnancy), and extreme PAU (hospital admissions/ presentations for alcohol-related diagnosis during pregnancy). Multinomial logit models explored the associations between sociodemographic and clinical factors and degrees of PAU. A relative risk ratio (RRR) with a 95% confidence interval (CI) was used to measure associations.

Results There were 19,588 births to 16,199 women during the study period (6,310 births to 5,207 Aboriginal women). The mean gestational age at birth for Aboriginal women was 37.8 (95% CI: 37.7, 37.9) weeks and 38.7 (38.6, 38.8) weeks for non-Aboriginal women. The overall PAU prevalence for births to Aboriginal women was 13.1% (95% CI: 12.2, 14.0), including 5.9% (95% CI: 5.2, 6.5) early PAU, 4.3% (95% CI: 3.8, 4.8) continued PAU, and 2.8% (95% CI: 2.4, 3.3) “extreme” PAU. The overall prevalence for non-Aboriginal women was 2.3% (95% CI: 2.1, 2.6), including 1.7% (95% CI: 1.5, 1.9), 0.53% (95% CI: 0.4, 0.7) and 0.1% (95% CI: 0.02, 0.1) for each category, respectively. Age, smoking, and substance misuse-related hospitalisation were associated with an increased risk of PAU among both populations.

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Being a victim of violence was an additional risk among Aboriginal women. More than five antenatal care (ANC) visits were associated with less PAU. However, 17.9% ($n=3520$) of births had missing records related to PAU.

Conclusion The study provides refined prevalence estimates for PAU across groups with increasing risk of harm. Early identification and effective engagement with women at risk of PAU are critical for improving outcomes for mothers and their children. Targeted interventions like enhanced services that support cessation of alcohol and other drugs (AOD), strengthening families, and sustained engagement with culturally safe, trauma-informed maternity care may aid in reducing PAU. The study also highlights the critical need to enhance both the quality and completeness of the routine recording of alcohol use during pregnancy.

Keywords Alcohol, Antenatal care, Mental health, Pregnancy, Smoking, Violence

Introduction

Prenatal Alcohol Use (PAU) is a global public health concern and a preventable cause of adverse pregnancy and childhood outcomes [1–3]. It increases the risk of physical, cognitive, behavioural, and psychological deficits in children, including intrauterine growth restriction and neurodevelopmental delays [4, 5]. PAU is also linked to a range of congenital disabilities, structural central nervous system (CNS) anomalies, and irreversible impairment of CNS functions, known as Fetal Alcohol Spectrum Disorder (FASD) [3–6].

PAU has teratogenic effects on the unborn baby; there is no safe amount or time to take alcohol during pregnancy [7–10]. Nonetheless, worldwide, pregnant women consume alcohol in varying amounts [8, 9, 11, 12], with a global estimate of 9.8% of women using alcohol during pregnancy [13, 14]. The rates of PAU vary across countries and regions in the same country. Estimates range from 4% to 27% in Denmark [15–18], 4.5% in Finland [19], 16% in Korea [20], and spans from 5.4% to 40.7% in Spain [21, 22]. Sweden reports a rate of 6% [23], while Japan ranges from 2.8% to 10.8% [24, 25]. The Netherlands reported 27.8% [26], and in the USA, estimates range from 6% to 49% [27–33], Russia reported 9.4% [34], and the United Kingdom exceeds 50% [8]. A systematic review and meta-analysis conducted in 2022 showed that the prevalence of PAU in Australia was 48% [35]. In Western Australia, the prevalence of PAU was 19.9% in 2011 and 23.1% in 2013 [36, 37]. In South Australia, the prevalence in 2014 was 29% in the 1st trimester and 26% in the 2nd and 3rd trimesters [38]. In the Northern Territory (NT) of Australia, the prevalence of PAU, estimated from linked data (1999–2004) was 11.9% [39]. According to the Australian Institute of Health and Welfare, 28% of pregnant women reported consuming alcohol during pregnancy in 2022–23 [40].

In Australia, the NT has the highest per capita consumption of alcohol, the highest rate of risky alcohol consumption, and the country's highest rates of hospitalisations related to alcohol misuse [41]. In the NT, Aboriginal and Torres Strait Islander communities, respectfully hereafter referred to as Aboriginal communities, have

higher alcohol use than non-Aboriginal Australians [42, 43]. However, accurately estimating alcohol consumption among women is still challenging [35]. The Australian Institute of Health and Welfare reported alcohol use during pregnancy in national records for the first time in 2019.

The reported prevalence of PAU varies widely across different populations and studies. Cultural beliefs and drinking habits can influence prenatal alcohol use. Additionally, studies defined PAU in various ways, such as occasional drinking versus heavy or binge drinking, which affects the reported prevalence. This difference in operational definitions may affect the reported prevalence and patterns of PAU and hinder more refined assessments of the impacts of volume and levels of PAU on maternal and child health outcomes. The methods used to measure alcohol consumption also vary—some studies rely on self-reported surveys [15, 16, 18, 20, 21, 24], while others use structured interviews or standardised screening tools [33, 37, 38]. The size and representativeness of the study sample also play a role, as some studies use small [21, 26, 28, 30, 37] or specific groups rather than more extensive and diverse populations. These factors contribute to inconsistencies in PAU estimates across studies.

PAU is affected by individual and community factors, such as socioeconomic status [15, 23, 24, 28, 37, 44], behaviours [15, 22–24, 34, 37, 44, 45], healthcare access [34], and environmental factors [23]. Furthermore, the coronavirus pandemic in 2019 [46], unplanned pregnancy [15, 22, 44, 47], gestational age [21, 27, 48, 49], violence and mental health-related conditions [11] were associated risk factors. Awareness of these risk factors plays an essential role in informing strategies to reduce PAU-related problems, including Fetal Alcohol Spectrum Disorders (FASD) [9]. The burden of FASD in Australia is unknown, and in the NT, it was estimated between 1.87 and 4.7 per 1000 live births [50].

Past PAU prevalence studies, including in the NT, have a range of limitations. Many have relied on a single dataset and have overlooked certain population groups with, for example, only a few studies estimating PAU

prevalence among Aboriginal women [51]. Furthermore, little is known about PAU and its risk factors. This study addresses these gaps using population-level datasets from the NT to improve PAU prevalence estimates' accuracy, determine PAU exposure degrees, and identify factors associated with PAU. Moreover, this study highlights the use of multiple data sources for comprehensive prevalence estimation and creates a PAU risk profile rather than just crude classification (yes or no). This study aims to assess the prevalence and factors associated with PAU among Aboriginal and non-Aboriginal women in the Northern Territory.

Methods

Study setting

The NT is a sparsely populated region in the north and central parts of Australia, with a population of approximately 248,151, including a substantial proportion (26.3%) of whom are Aboriginal Australians [52, 53]. Healthcare services in the NT are provided through a network of government and non-government services, including government primary care services, Aboriginal Community Controlled Health Organisations (ACCHOs), private practitioners and hospital services [54].

Study design and data sources

This study used a population-based cross-sectional design. The data used in this study was obtained from a repository of linked administrative datasets set up through the Child and Youth Development Research Partnership (CYDRP) [55]. The study used three data sources - the NT perinatal data register, NT public

hospital admissions, and hospital emergency department presentations [39, 56, 57].

The NT perinatal data register, established in 1986, is a statutory collection of comprehensive information on antenatal care and birth outcomes for all births in the NT. We utilised the most recent data available in the CYDRP data repository from 2013 to 2017 to estimate the prevalence.

The NT hospital admission (Inpatient Activity) dataset includes diagnoses and procedures for all patients admitted to any of the six NT public hospitals. We linked the NT hospital admission data with the perinatal register for the years 2013–2017 to identify births to mothers with a diagnosis of an alcohol-related condition during pregnancy. Hospital admissions data was also used to identify admissions of women during pregnancy with a diagnosis of mental health-related hospitalisation, substance misuse-related hospitalisation, violence-related condition or self-harm. These lists of conditions are available in the ICD-10 International Disease Classification codes (Supplementary files 1a & 1b).

The third data set was the NT hospital emergency department (ED) presentations. Like hospital admissions data, we linked the NT ED presentation data with the perinatal register for the years 2013–2017 to identify births to mothers who had a diagnosis of an alcohol-related condition during pregnancy. Figure 1 illustrates the process of merging the three datasets to create the study population. Pregnancy duration was defined from conception to birth, estimated as date of birth minus (gestational weeks $\times$ 7), with birth date recorded in the perinatal registry.

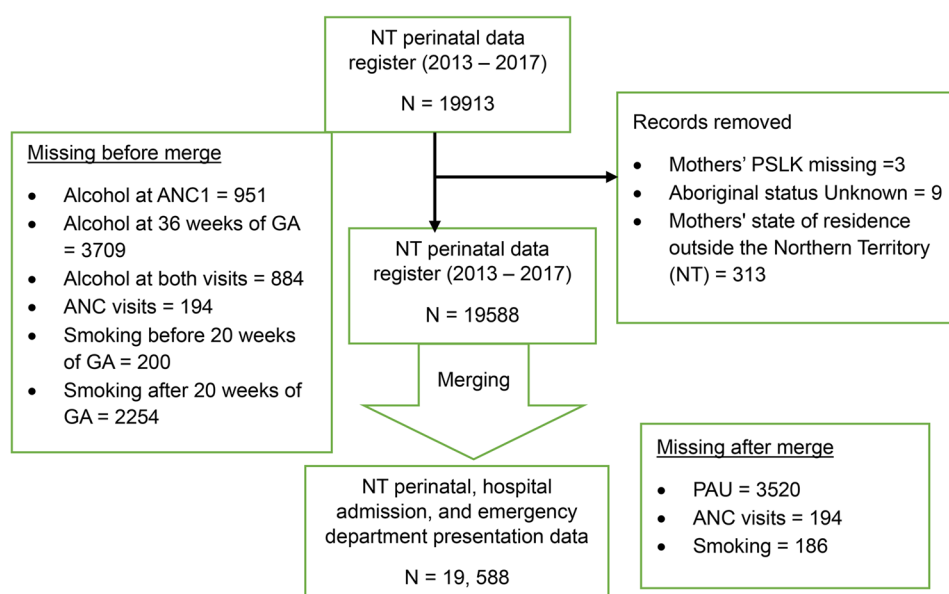


Fig. 1 Merging process of the NT Perinatal registry, Hospital admission, and emergency department presentations

Measurement of the dependent variable (PAU)

This study combined alcohol measurement from four different sources: self-reported alcohol use at the first antenatal visit (yes/no) and self-reported alcohol use at 36 gestational weeks (yes/no), as recorded in the NT perinatal data register, diagnoses that are 100% alcohol-attributable conditions from NT hospital admission, and cases that are 100% alcohol-attributable conditions from NT hospital emergency department presentations [58]. These conditions included the International Classification of Diseases (ICD-10) codes [58] for alcohol abuse (F10.0, F10.1), alcohol dependence syndrome (F10.2), alcoholic psychosis (F10.3 – F10.9), alcoholic gastritis (K29.2), alcoholic liver diseases (K70.0 – K70.4, K70.9), alcohol-induced acute pancreatitis (K85.2), alcoholic poisoning (Y15), and intentional self-harm by and exposure to alcohol (X65).

Classification of PAU

We used permutation-based analysis to combine the four sources of alcohol measurement to create a matrix of 36 combinations, which was developed using Microsoft 365 and Power Query in Excel (Version 2410, 2022) (Supplementary file 2).

This study then classified the 36 possible combinations into five PAU categories. The first category was births to mothers with a record of No PAU, which consisted of women with a record of no alcohol consumption at their first antenatal visit and no alcohol consumption at the ANC visit at 36 weeks of gestation and no record of an alcohol-related condition during pregnancy reported in emergency department records and hospital admission records. The second category, Early PAU, includes those births to mothers with a record of alcohol use at their first antenatal care visit and a record of no alcohol use at 36 weeks of gestation and no record of an alcohol-related episode in the emergency department and hospital admission records. The third category, Continued PAU, consisted of births in which mothers reported alcohol use at 36 weeks of gestation alone or at both first and 36-week antenatal care visits but with no record of an alcohol-related diagnosis in the emergency department or hospital admission records. The fourth category is Extreme PAU, which includes births in which mothers had a record of reported alcohol use at both antenatal care visits and had alcohol-related conditions requiring emergency department visits or hospital admission. This category covers Alcohol Use Disorders (AUD), including alcohol abuse, alcohol dependence, and alcoholic psychosis, as well as alcohol-related diseases such as alcoholic gastritis, alcoholic liver disease, alcohol-induced acute pancreatitis, and alcohol poisoning. The fifth category is Unknown Prenatal Alcohol Use, “or” “Unknown PAU”, which includes those births to mothers for whom

there is no information on alcohol exposure in perinatal data (Supplementary file 2). Those births to women, with incomplete records for PAU in the perinatal data were grouped based on the available information, for example, those with a record of alcohol use at the first ANC visit but no record at 36 weeks were classified as “Early PAU”, while those with no record at first ANC visit but a record of PAU at 36 weeks were classified as “Continued PAU”.

Explanatory variables

Age of the mother (continuous), ANC visits (recoded as ≤ 4 and ≥ 5 visits), smoking (yes/no), all forms of violence (yes/no) – defined as violence other than assault, different forms of assaults, and perpetrator of neglect and maltreatment 12 months before and during pregnancy, mental health-related hospitalisation (yes/no) – defined as hospital admission and/or emergency presentation due to severe mental health disorders, common mental health disorders, and personality disorders 12 months before and during pregnancy, substance misuse-related hospitalisation (yes/no) – defined as hospital admission and/or emergency presentation due to behavioural and mental health disorder due to psychoactive Substance use 12 months before and during pregnancy, and self-harm (yes/no) – defined as hospital admission and/or ED presentation due to intentional self-harm 12 months before and during pregnancy were independent variables considered during multinomial logit model. The ICD-10 codes used to flag these conditions were explained elsewhere [59]. We used the datasets of the NT perinatal data register, hospital admissions and emergency department presentations (Supplementary files 1a & 1b).

Missing value handling

The perinatal data register (2013–2017) has the following missing: alcohol at the first ANC visit ($n=951$, 4.9%), alcohol at 36 weeks of gestation ($n=3709$, 18.9%), smoking before 20 weeks of gestation ($n=200$, 1.0%), smoking after 20 weeks of gestation ($n=2254$, 11.5%), and ANC visits ($n=194$, 1.0%). Moreover, the mother’s project-specific linkage key (PSLK) for three mothers was missing, the Aboriginal status of nine mothers was unknown, and 313 individuals were non-NT residents. These (missing pslk, unknown Aboriginal status, and non-NT residents) records were removed before merging (Fig. 1). After combining the datasets, three variables – PAU ($n=3520$, 18.0%), ANC visit ($n=194$, 1.0%), and smoking ($n=186$, 1.0%) had missing values. Aboriginal women were more likely to have missing alcohol records than non-Aboriginal women (p -value < 0.05). We created a binary missing indicator variable (yes/no) for sensitivity analysis. We fitted a binary logistic regression model for factors related to missingness among Aboriginal and non-Aboriginal women. So, women being treated in public hospitals,

non-smokers and women having less than 5 ANC visits tended to have more missing than their counterparts among Aboriginal women. At the same time, women with Substance misuse-related hospitalisation and older age were less likely to have missing PAU records. For non-Aboriginal women, women with less than 5 ANC visits, who experienced violence, those treated in public hospitals, and smokers had a higher probability of missing data for PAU. However, advanced maternal age was associated with a lower likelihood of missing among non-Aboriginal women.

The final prevalence estimation and multinomial logit model were based on the complete dataset (82%), as

it is not recommended to use imputation for the outcome variable [60]. Moreover, we did not impute the outcome variables due to the following reasons: (i) sufficient birth records were available to estimate PAU, and (ii) the impact of missing data on model coefficients was minimal [61]. Moreover, the missing values among different population characteristics were distributed equally among Aboriginal and non-Aboriginal women. Smoking and ANC variables had very few missing values (<1%); thus, we used a complete case analysis technique. A detailed description of missing values for PAU and other covariates is provided in the supplementary file (Supplementary file 3).

Table 1 Pregnant women's sociodemographic and clinical characteristics, NT, Australia, 2013 – 2017 ($n = 19,588$)

Variables	Frequency (%)
Age of mothers at delivery	
Less than 20 Years	1367 (7.0%)
20 – 24 years	3738 (19.1%)
25 – 29 years	5552 (28.3%)
30 – 34 years	5650 (28.8%)
35+ years	3281 (16.8%)
Age of the mother	Mean = 28.61 (95% CI: 28.52, 28.69)
Aboriginal status of the mother	
Aboriginal	6310 (32.2%)
Non-Aboriginal	13278 (67.8%)
Epidemiological Districts	
Darwin Urban	11467 (58.5%)
Darwin Rural	1396 (7.1%)
Kathrine	1717 (8.8%)
East Arnhem	1099 (5.6%)
Barkly	558 (2.9%)
Alice Spring Urban	2229 (11.4%)
Alice Spring Rural	1051 (5.4%)
ANC visits	
Less than five visits	1499 (7.7%)
5+ visits	17895 (91.3%)
Unknown	194 (1.0%)
Smoking status	
Nonsmokers	15261 (77.9%)
Smokers	4141 (21.1%)
Unknown	186 (1.0%)
All forms of violence	
Yes	613 (3.1%)
No	18975 (96.9%)
Substance misuse-related hospitalisation	
Yes	425 (2.1%)
No	19163 (97.9%)
Mental health-related hospitalisation	
Yes	336 (1.7%)
No	19252 (98.3%)
Self-harm	
Yes	72 (0.4%)
No	19516 (99.6%)

Data analysis

PAU was categorised into four categories (1 = No PAU, 2 = Early PAU, 3 = Continued PAU, and 4 = Extreme PAU). We used a multinomial logit model to analyse factors associated with PAU, as the assumption of proportional odds needed for ordinal logistic regression was not satisfied [62, 63]. We tested for multicollinearity, and none of the covariates were highly correlated (all variance inflation factors were below 10). Descriptive statistics, such as percentages, graphs, and tables, were used to summarise the data. Prevalence was calculated by dividing each category's cases by the total births, then multiplying by 100. A chi-square test of independence was used to determine the relation between PAU and Aboriginal status. As the PAU burden amongst Aboriginal and non-Aboriginal births was substantially different ($p < 0.05$), separate multinomial logistic regression models were developed for each population. Relative Risk Ratio (RRR) and 95% confidence intervals (CIs) were used to measure the strength of the association between PAU and risk factors. Statistical significance was declared at a 5% level.

Results

Description of pregnant women's records

Table 1 presents the characteristics of the records of pregnant women in the study. Between 2013 and 2017, 19,588 live births and stillbirths were recorded across various health facilities. The mean gestational age at birth for Aboriginal women was 37.8 (95% CI: 37.7, 37.9) weeks and 38.7 (38.7, 38.8) weeks for non-Aboriginal women. Geographically, these mothers were distributed across different epidemiological districts. Darwin Urban accounted for the most significant proportion (58.5%). Most of these births (97.5%) were singletons. These births were from 16,199 mothers, with an average maternal age of 28.6 years (95% CI: 28.5–28.7). Seven per cent of mothers (1,367) were Younger than 20 years, and 19.1% (3,738) were aged 20–24. A total of 6,310 mothers (32.2%) identified as Aboriginal (Table 1).

Table 2 The prevalence of PAU among aboriginal and non-Aboriginal women, NT, AU

Levels of PAU	Prevalence (95% CI)	
	Aboriginal births (<i>n</i> = 5,027)	Non-Aboriginal births (<i>n</i> = 11,041)
No PAU	86.9% (85.9, 87.8)	97.6% (97.4, 97.9)
Early PAU	5.9% (5.3, 6.6)	1.7% (1.5, 2.0)
Continued PAU	4.3% (3.8, 4.9)	0.5% (0.4, 0.7)
Extreme PAU	2.9% (2.4, 3.3)	0.1% (0.0, 0.1)
Total PAU (any)	13.1% (12.2, 14.0)	2.3% (2.1, 2.6)

Chi-Square (3) = 811.6, *p*-value < 0.001**Prevalence of prenatal alcohol use**

The total prevalence of PAU for all births was 5.7% (95% CI: 5.4, 6.1), including 3.0% (95% CI: 2.8, 3.3) early PAU, 1.7% (95% CI: 1.5, 1.9) continued PAU, and 1% (95% CI: 0.8, 1.1) extreme PAU. A chi-square test of independence confirmed a strong association between PAU prevalence and Aboriginal status ($\chi^2(3) = 811.6$, $p < 0.001$), showing that alcohol consumption patterns during pregnancy vary significantly by Aboriginal status. Thus, a separate estimation shows that the prevalence of PAU for all births to Aboriginal women was 13.1% (95% CI: 12.2, 14.0), including 5.9% (95% CI: 5.3, 6.6) early PAU, 4.3% (95% CI: 3.8, 4.9) continued PAU, and 2.9% (95% CI: 2.4, 3.3) “extreme” PAU. The total prevalence for non-Aboriginal women was 2.3% (95% CI: 2.1, 2.6), including 1.7% (95% CI: 1.5, 2.0), 0.5% (95% CI: 0.4, 0.7) and 0.1% (95% CI: 0.0, 0.1) for each category, respectively (Table 2).

The most frequent alcohol-related conditions diagnosed at hospital admissions and ED presentations for women during pregnancy were alcohol abuse (F10.0 – F10.1) and alcoholic gastritis (K29.2), with alcohol abuse recorded for all 96 alcohol-related hospital admissions

and 80 of 82 ED alcohol-related presentations, while alcoholic gastritis was diagnosed for 5 of 96 alcohol-related hospital admissions and 5 of 82 alcohol-related ED presentations.

However, 17.9% (*n* = 3520) of births had missing records related to PAU. Moreover, births taking place in public hospitals, non-smoking mothers, and women having less than 5 ANC visits tended to have more missing data than their counterparts among Aboriginal women. Similarly, women with Substance misuse-related hospitalisation and older age were less likely to have missing PAU records. For non-Aboriginal women, women with less than 5 ANC visits, who experienced violence, those treated in public hospitals, and smokers had a higher probability of missing data for PAU. However, maternal age was associated with a lower likelihood of missing among non-Aboriginal women (Supplementary File 3).

Factors associated with PAU**Model for aboriginal women**

In multivariable analysis, Aboriginal women who smoked during pregnancy were six times more likely to consume alcohol in early pregnancy compared to non-smokers (aRRR (adjusted relative risk ratio) = 6.01; 95% CI: 4.38–8.24). Maternal age was also associated with a higher likelihood of early PAU, with each additional year increasing the risk by 5.6% (aRRR = 1.05; 95% CI: 1.03–1.07). Violence (aRRR = 2.17; 95% CI: 1.41, 3.36) and substance misuse-related hospitalisation (aRRR = 2.98; 95% CI: 1.81, 4.90) were also associated with early PAU, compared to those without such experiences (Table 3).

Maternal age was further associated with continued PAU, with each additional year of age increasing the risk by 7% (aRRR = 1.07; 95% CI: 1.04–1.09). Women who

Table 3 A multinomial logistic regression showing factors associated with the level of prenatal alcohol use among aboriginal women in the NT, Australia

Covariates	Early PAU		Continued PAU		Extreme PAU	
	Crude RRR (95% CI)	aRRR (95% CI)	Crude RRR (95% CI)	aRRR (95% CI)	Crude RRR (95% CI)	aRRR (95% CI)
Age of mothers	1.05 (1.03, 1.07) *	1.05 (1.03, 1.07) *	1.06 (1.04, 1.08) *	1.07 (1.04, 1.09) *	1.03 (1.01, 1.06) *	1.02 (0.98, 1.06)
ANC visits						
0 – 4 visits	1	1	1	1	1	1
5 and above	0.81 (0.58, 1.14)	0.92 (0.65, 1.31)	0.48 (0.35, 0.68) *	0.57 (0.41, 0.82) *	0.41 (0.28, 0.60) *	0.55 (0.31, 1.00) *
Smoking status						
Non-smokers	1	1	1	1	1	1
Smokers	6.08 (4.46, 8.28) *	6.01 (4.38, 8.24) *	8.30 (5.56, 12.41) *	7.70 (5.13, 11.56) *	2.77 (1.93, 3.97) *	2.66 (1.56, 4.53) *
Substance misuse-related hospitalisation						
No	1	1	1	1	1	1
Yes	4.74 (3.10, 7.26) *	2.98 (1.81, 4.90) *	6.22 (3.99, 9.69) *	2.98 (2.13, 6.18) *	-	-
All forms of violence						
No	1	1	1	1	1	1
Yes	3.03 (2.08, 4.39) *	2.17 (1.41, 3.36) *	3.93 (2.65, 5.82) *	2.52 (1.55, 4.09) *	51.69 (35.1, 76.1) *	3.75 (2.24, 6.30) *

Variables entered the model: Age, ANC, Smoking, substance misuse-related hospitalisation, violence, mental health-related hospitalisation, and self-harm. RRR means relative risk ratio, aRRR means adjusted RRR, CI means Confidence Interval, and * shows statistical significance at 5% alpha

Table 4 A multinomial logistic regression showing factors associated with the level of prenatal alcohol use among non-Aboriginal women in the NT, Australia

Covariates	Early PAU		Continued PAU		Extreme PAU	
	Crude RRR (95% CI)	aRRR (95% CI)	Crude RRR (95% CI)	aRRR (95% CI)	Crude RRR (95% CI)	aRRR (95% CI)
Age of mothers	0.97 (0.94, 1.00)	1.00 (0.97, 1.03)	1.03 (0.98, 1.08)	1.07 (1.02, 1.12)*	0.95 (0.84, 1.08)	1.07 (0.94, 1.21)
ANC visits						
0 – 4 visits	1	1	1	1	1	1
5 and above	0.56 (0.31, 1.03)	0.77 (0.42, 1.42)	0.24 (0.11, 0.51)*	0.33 (0.15, 0.72)*	0.31 (0.04, 2.47)	0.63 (0.06, 6.75)
Smoking status						
Non-smokers	1	1	1	1	1	1
Smokers	8.53 (6.33, 11.51)*	8.52 (6.23, 11.6)*	13.4 (7.97, 22.36)*	14.1 (8.12, 24.3)*	6.45 (1.61, 25.86)*	0.62 (0.13, 2.89)
Substance misuse-related hospitalisation						
No	1	1	1	1	1	1
Yes	2.7 (0.65, 11.25)	0.98 (0.22, 4.14)	18.59 (6.44, 53.6)*	5.98 (1.9, 18.79)*	-	-

Variables entered the model: Age, ANC, smoking, substance misuse-related hospitalisation, violence, mental health-related hospitalisation, and self-harm. *RRR* means relative risk ratio, *aRRR* means adjusted RRR, *CI* means Confidence Interval, and * shows statistical significance at 5% alpha

experienced violence were 2.5 (aRRR=2.52; 95% CI: 1.55, 4.09) times more likely to continue alcohol consumption during pregnancy, while those with Substance misuse-related hospitalisation were 3.6 (aRRR=3.63; 95% CI: 2.13, 6.18) times more likely to continue drinking alcohol in pregnancy. Smoking during pregnancy was strongly associated with continued PAU, with women who smoked being 7.7 (aRRR=7.70; 95% CI: 5.13–11.56) times more likely to continue drinking during pregnancy. However, attending more than five antenatal care (ANC) visits was associated with a lower likelihood of continued PAU of 42% (aRRR=0.57; 95% CI: 0.41, 0.82) compared to those with fewer visits (Table 3).

Smoking during pregnancy was strongly associated with extreme PAU, with women who smoked being 2.6 (aRRR=2.65; 95% CI: 1.56, 4.53) times more likely to be hospitalised with an alcohol-related condition during pregnancy. Those who experienced any form of violence had an even higher risk, being 3.7 (aRRR=3.75; 95% CI: 2.24, 6.30) times more likely to be hospitalised with an alcohol-related condition during pregnancy. On the other hand, attending more than five antenatal care (ANC) visits significantly reduced the risk of alcohol-related hospital admissions by 44% (aRRR=0.55; 95% CI: 0.31, 1.00) compared to women with fewer than 5 ANC visits (Table 3).

Model for non-Aboriginal women

The multinomial logistic regression analysis for non-Aboriginal women revealed significant associations between smoking, age of the mother, antenatal care visits, and substance misuse-related hospitalisation with the categories of PAU. Non-Aboriginal women who smoked during pregnancy were eight times more likely to be in the category of early PAU compared to women with the category of no smoking (aRRR=8.52; 95% CI: 6.23, 11.6) (Table 4).

Older non-Aboriginal women were more likely to drink alcohol in late pregnancy, with each additional year of age increasing the risk by 7% (aRRR=1.07; 95% CI: 1.02–1.12). Non-Aboriginal women who had Substance misuse-related hospitalisation were 6 times more likely to drink alcohol in late pregnancy compared to those who did not experience such substance misuse-related hospitalisation (aRRR=5.98; 95% CI: 1.9, 18.79). Similarly, smoking during pregnancy increased the risk of drinking alcohol in late pregnancy by nearly 14 times (aRRR=14.1; 95% CI: 8.12, 24.3). In contrast, attending more than five ANC visits reduced the likelihood of continuing drinking alcohol in late pregnancy by 67% compared to those with fewer ANC visits (aRRR=0.33; 95% CI: 0.15, 0.72) (Table 4).

Discussion

This study examined the prevalence of PAU in the Northern Territory using linked individual-level administrative datasets and explored factors associated with varying degrees of PAU. The overall PAU prevalence for births to Aboriginal women was 13.1% (95% CI: 12.2, 14.0), including 5.9% (95% CI: 5.2, 6.5) early PAU, 4.3% (95% CI: 3.8, 4.8) continued PAU, and 2.8% (95% CI: 2.4, 3.3) “extreme” PAU. The overall prevalence for non-Aboriginal women was 2.3% (95% CI: 2.1, 2.6), including 1.7% (95% CI: 1.5, 1.9), 0.53% (95% CI: 0.4, 0.7) and 0.1% (95% CI: 0.02, 0.1) for each category, respectively. Advancing maternal age, tobacco smoking, and substance misuse-related hospitalisation were associated with all degrees of PAU in both Aboriginal and non-Aboriginal women. Violence-related hospitalisation was associated with PAU in Aboriginal births only. Women who had more than five antenatal clinic visits had a lower risk of PAU.

The prevalence of PAU was higher among Aboriginal women than non-Aboriginal women. The national perinatal data collection included prenatal alcohol use as an indicator for the first time in 2019, and for consecutive

years, it has reported a significant difference in the prevalence of PAU among Aboriginal and non-Aboriginal Australians [64]. Similarly, the 2021 report of mothers and babies of the Northern Territory showed a higher prevalence of PAU among Aboriginal women than non-Aboriginal women (8% vs. 2%) [43]. This finding was consistent with a study conducted in Canada and the United States of America [65, 66], where Aboriginal women in Canada and the USA were at higher risk of PAU than their non-Aboriginal counterparts. Significant health disparities between Aboriginal and non-Aboriginal people continue to exist, including life expectancy rates, poorer perinatal outcomes, higher chronic disease rates, etc. Factors contributing to these disparities include social determinants of health, health risk factors, cultural barriers, and poorer access to healthcare services [66, 67]. Moreover, intergenerational trauma, historical disadvantage, systemic discrimination, and unbalanced implementation of past and current policies have contributed to poorer social and health outcomes among Aboriginal people [68, 69].

The higher prevalence of PAU among Aboriginal women shows the need for improved public health efforts. Addressing key factors, including health literacy, health care access, smoking and other Substance misuse, socioeconomic disadvantage, and poverty, is crucial to reducing PAU. Culturally aware and safe healthcare services are the cornerstone to closing this gap. Strengthening the NT Health Aboriginal Cultural Security Framework 2016–2026 implementation can enhance culturally safe and responsive healthcare, improving access and engagement for Aboriginal women [70]. Additionally, fully executing strategies within the *Closing the Gap* initiative may help reduce health disparities by addressing systemic inequalities [71, 72]. Community-driven approaches incorporating “Indigenous knowledge” can improve intervention effectiveness [73]. Tailored education, support programs, and accessible antenatal care services can empower Aboriginal women to make informed choices about PAU.

Tobacco smoking was a consistent predictor of PAU among both Aboriginal and non-Aboriginal women. Women who smoked during pregnancy were at a higher risk of consuming alcohol at an early stage of pregnancy, late pregnancy, and being exposed to extreme levels of PAU. Previous studies also showed the association between smoking and PAU [23, 32, 34, 37, 45, 74–78]. This association could be due to shared social contexts where smoking and alcohol are often practised in common places and occur together in places like parties, bars, and gatherings. Here, the role of peer influence is high, where friends who engage in one behaviour encourage the other [11, 79]. The other reason could be that both substances are used as a coping mechanism for

stress, anxiety, or emotional distress. Moreover, women who are addicted to one of the substances may be more likely to use the other due to the addiction cycle, as these substances create dependence. A study conducted in the USA showed that there was a dose-response relationship between alcohol use, tobacco use and nicotine dependence [70]. Alcohol dependence and addiction are serious concerns. AUD involves intense cravings, loss of control, and physical dependence. Pregnant women with AUD require a holistic approach that addresses psychological, physical, and social factors associated with alcohol addiction. This may involve an alcohol detox program, behavioural therapy, medication-assisted treatment, and support groups and peer-led programs [80, 81]. The other possible reason could be that the neurological links created for the reward system overlap to generate dopamine and create pleasure sensations [82]. Cross-tolerance between alcohol and cigarettes could be another reason why the interaction between these two substances enhances the effects of the other [83, 84]. Moreover, these two unhealthy behaviours have behavioural linkage and are expressed in the form of habit reinforcement, where smoking reinforces alcohol and vice versa, and their craving and triggering effects [85, 86].

This study showed that women who were diagnosed with any Substance misuse-related disorders were 3 times at higher risk among Aboriginal and 6 times at higher risk among non-Aboriginal women to engage in continued PAU. Previous studies were also consistent with this finding [87, 88]. It is known that alcohol and alcoholic beverages have ethanol, which is a psychoactive and toxic substance with dependence-producing properties, further relating PAU and substance misuse. This association could be due to pregnant women getting some pleasure due to the production of dopamine and serotonin when they feel depressed and have anxiety [82]. Moreover, these behavioural disorders among pregnant women could lead them to the use of psychoactive substances such as alcohol. Thus, considering the adverse effects of mental health issues on the prevalence of PAU, urgent interventions should be designed and implemented that adequately address any known or undiagnosed mental health disorders that may be associated with alcohol or other substance misuse. In addition, evidence-based recommendations by the Centre of Perinatal Excellence should be emphasised, including screening and assessing pregnant women via administering the antenatal risk questionnaire to determine a woman’s psychosocial risk [89].

The present study showed that Aboriginal women who experienced any form of violence were at a higher risk of drinking alcohol than those who did not. The association between violence and PAU is complex and influenced by multiple social, psychological, and behavioural factors.

More importantly, violence in various forms—including intimate partner violence (IPV) and family violence—is a significant public health and social concern in Australia [90, 91]. Women who experience violence may suffer from physical injuries, emotional distress, and long-term psychological conditions, such as depression, anxiety, post-traumatic stress disorder (PTSD), and self-harming tendencies. These consequences can severely affect a woman's well-being and decision-making during pregnancy [90–92].

One primary reason for the association between violence and PAU is that women may use alcohol as a coping mechanism to deal with the trauma, fear, and emotional pain caused by violence [11]. In this situation, alcohol intake may provide temporary relief from stress and anxiety, making it an accessible but harmful coping mechanism. However, this behaviour may increase the risk of PAU, leading to potential harm to both the mother and the unborn child [11, 92]. Partners who consume alcohol may influence PAU. Research suggests that women who drink alcohol during pregnancy are more likely to have partners who also consume alcohol heavily. In relationships where alcohol consumption is prevalent, there is a higher likelihood of alcohol-fuelled aggression and violence, which can further escalate the cycle of abuse [92]. As described in Australian clinical practice guidelines, considering culturally appropriate psychosocial risk assessment during antenatal care is crucial for early identification and intervention of factors affecting mental health, including violence [89].

This study implies the need for integrated public health strategies to reduce PAU. Reducing PAU requires culturally safe, trauma-informed maternity care, adequate and effective mental health support, and community-driven interventions that strengthen relationships and families [93]. Intersectoral collaboration between healthcare providers, social workers, and family violence support services is essential, as is ensuring access to safe housing, legal support, and counselling. Interventions should also target alcohol use among partners, promote healthy relationships, and implement community-based programs to reduce alcohol use. Strengthening policies on family violence protection, improving reporting systems, and raising public awareness can help with early intervention [90, 94, 95]. Reducing violence requires a holistic approach that combines healthcare, social support, and policy measures. Community-led programs involving Aboriginal leaders improve service access and effectiveness, which in turn helps lower PAU prevalence and promotes better maternal and child health outcomes.

This study emphasises the role of antenatal care (ANC) in reducing PAU. Five or more ANC visits significantly increase the likelihood of quitting or reducing prenatal alcohol use. Previous studies have shown similar

associations between increased antenatal care and either abstinence from PAU, reduction of use, or stopping PAU [96, 97]. Routine alcohol screening and prompt interventions during ANC can help identify at-risk women early. ANC also offers opportunities for targeted education, counselling, and interventions to promote alcohol abstinence [98, 99]. Reducing PAU improves maternal and fetal health, lowers perinatal mortality, and enhances pregnancy experiences. Culturally tailored interventions and policies should ensure accessibility and affordable ANC. The WHO highlights that addressing alcohol and drug use before, during, and after pregnancy is crucial for improving maternal and child outcomes [100].

This study also showed that for every one-year increase in maternal age, there was a 7% increase in the risk of PAU. This has been echoed in similar studies [23, 37, 51, 76, 101, 102]. Tailored education efforts should consider the mothers' age.

Strengths and limitations

Prospectively collected data from multiple data sources and representative data are used to reduce recall bias compared to retrospectively collected data. Furthermore, permutation techniques used to create informative alcohol categories from routinely collected healthcare data are a strength of this study. However, since perinatal data is based on self-reported information on alcohol use, the result may be subject to social desirability bias, which tends to underestimate the prevalence of PAU. Moreover, a significant proportion of missing data on PAU might underestimate its prevalence. However, to reduce the effects of these limitations, we supplemented perinatal data with the NT hospital admission and emergency department presentation data, which hold clinically diagnosed wholly alcohol-related conditions based on the International Classification of Diseases (ICD-10). In addition to these, the frequency and dose of alcohol use during pregnancy are not measured; this inhibits us from considering our data as ordinal (proportional odds assumption failed). Some wider confidence intervals in estimating the relative risk ratio due to a small number of cell frequencies may reduce the estimate's accuracy. This study did not include potential factors affecting alcohol use, such as social and peer pressure, awareness, beliefs about alcohol, pregnancy planning, and treatment options. Besides, due to the study design, we could not figure out the temporal relationship between the prevalence of PAU and its associated factors. Thus, readers should consider these limitations when interpreting and using the results of this study.

Conclusions

The study provides refined prevalence estimates for PAU across groups with increasing risk of harm. Early identification and effective engagement with women at risk of PAU are critical for improving outcomes for mothers and their children. Targeted interventions like enhanced services that support cessation of alcohol and other drugs (AOD), strengthening families (particularly for women who are affected by family and domestic violence), and sustained engagement with culturally safe, trauma-informed maternity care may aid in reducing PAU. The study also highlights the critical need to enhance both the quality and completeness of the routine recording of alcohol use during pregnancy.

Abbreviations

ACCHO	Aboriginal Community Controlled Health Organisations
ANC	Antenatal care
CI	Confidence Interval
CYDRP	Child and Youth Development Research Partnership
FASD	Fetal Alcohol Spectrum Disorder
ICD	International Classification of Diseases
PAU	Prenatal Alcohol Use
NT	Northern Territory
PSLK	Project Specific Linkage Key
RRR	Relative Risk Ratio

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12884-025-08216-5>.

Additional file 1: Supplementary file.

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Authors' contributions

BD, AD, HP, and SG played a substantial role in the design, data linkage, data analysis, data visualisation, validation, and manuscript preparation. HU, KB, and DB played essential roles in data visualisation, validation, and manuscript preparation. All authors critically commented on and reviewed the manuscript. The authors have approved the final version of the manuscript and accept responsibility for all aspects of the work.

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Data availability

The datasets used and/or analysed in this study are available at the Child and Youth Development Research Partnership. Moreover, all information used to discuss and conclude the findings of this study is presented in tables and graphs and is attached in the form of supplementary information.

Declarations

Ethics approval and consent to participate

This study was approved by the Human Research Ethics Committee of the Northern Territory Department of Health and Menzies School of Health Research (HREC-2024-4852, 29/04/2024) and the Charles Darwin University Human Research Ethics Committee (CDU-HREC, H24069, 10/07/2024). It follows the National Health and Medical Research Council (NHMRC) guidelines, including ethical research involving Aboriginal women. The First Nation Advisory Group reviewed the project's benefits for Aboriginal and Torres Strait Islander children and youth (15/11/2023). Confidentiality is kept throughout data management, analysis, and interpretation, with a formal agreement (Data Security Declaration) outlining roles, responsibilities, and data use.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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